

PROGRESS REPORT NO. 11

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THE PROBLEM OF MAN'S GRAVITOINERTIAL FORCE ENVIRONMENT IN
SPACE FLIGHT

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John G. ...
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Facilities

A modest alteration is in progress involving the "vestibular laboratory annex" which will increase its usefulness very considerably.

Personnel

It is a source of real gratification to announce that Dr. Bo Gerhardt has decided to remain at the U. S. Naval Aerospace Medical Institute.

Prepublication Notes

Two areas of great interest under investigation are 1) the possibility that the semicircular canals are stimulated by linear accelerations and 2) the interaction between direct and indirect gravitational and visual cues in weightlessness and in subgravity states.

With regard to the first problem, there have been recent reports from our laboratory and elsewhere that nystagmus, ordinarily regarded as a response to stimulation of the semicircular canals by angular or Coriolis acceleration, is also produced by exposing persons to rectilinear accelerations when seated upright or to constant angular velocity when rotated about their long axis when horizontal to gravity. There is no doubt but that the nystagmus has its origin in the vestibular organs but there is only speculation as to whether it has its origin in the otolith apparatus, semicircular canals, or, somehow, in both vestibular organs. If recent experiments carried out jointly with Canadian investigators are confirmed, the semicircular canals are "implicated." In these investigations cats have been exposed to the force environment in a counter-revolving room (CRR). Angular acceleration is absent and centripetal force is generated by virtue of the radius between the CRR and the primary turntable or centrifuge. Cats in which only the otolith apparatus had been at least severely injured if not destroyed, manifested nystagmus as usual, while cats in which only the semicircular canal ducts had been occluded (at one location) did not.

The second problem deals with the eminently practical matter of man's orientation in an orbiting spacecraft or during extravehicular activities. In both situations man is exposed to inertial forces. Head movements, for example, generate the same angular velocities as under terrestrial conditions, and their effectiveness as a stimulus to the vestibular apparatus must be about the same as "normal" although the effect of this stimulus probably is influenced slightly by the loss in G loading. The response to off-axis impulses from the canals, however, may be significantly affected by the physiological deafferentation of the graviceptors which alters the "integrative pattern" in the central nervous systems.

The astronaut is also "exposed" to a variety of inertial forces generated by other bodily movements and by any perturbations of the spacecraft which may constitute effective stimuli to gravireceptors. Moreover, the astronaut, by virtue of contact with the spacecraft, tends to be cued to his vehicle even in absence of vision. These tactile and pressure cues in a weightless vehicle thus subserve the function of those cues which would provide similar information under terrestrial G loading.

The thorough investigation of these problems can be carried out only in spaceflight although the few seconds of weightlessness in parabolic flight may furnish some worthwhile information and, more importantly, indicate lines of direction for investigations aloft. It was with these thoughts in mind that some brief experiments were carried out in collaboration with the U. S. Air Force at Wright-Patterson Air Force Base, Ohio.

Some incidental observations of an aviator not experienced in parabolic flight provided the initial stimulus. While free-floating in the after-portion of the aircraft, he experienced "a sudden reversal of up and down." At least two additional factors seemed to be essential for the perception of this illusion. The more important of the two was a head-lower-than-feet position with reference to the cabin and the second condition was the necessity to face the forward end of the cabin, the great length of which had "the characteristics of a tunnel." The illusion lasted only a matter of seconds and had two related aspects, a bodily feeling of sudden reversal of the upright and a belief that the plane was flying upside down. He ascribed it to negative G, but this was almost ruled out by the fact that he was free-floating. The possibility that a thrust by hand or foot against the fuselage generated an adequate stimulus could not be ruled out but seemed unlikely.

The two brief experiments involved a comparison of responses in normal and avestibular (L-D) subjects under two different conditions in parabolic flight. In the first experiment the subjects encased in a Fiberglass mold rigidly secured to the KC 135 aircraft were exposed to parabolic maneuvers while in the dark. After completion of all trials, each subject was asked whether he experienced any change in body position during the weightless phase of the parabola. The two normal subjects stated that they perceived a sudden reversal in body position from "head-up" to "head-down" on entering weightlessness and a return to the head-up position on the pullout. This occurred in every parabolic maneuver regardless of body position in the tilt device. The L-D subjects did not experience this inversion on any occasion.

In the second experiment the subject's task was to walk on the overhead of the aircraft while exposed to negative G loads of around 0.05 G for 6 to 10 seconds. Five

normal and four L-D subjects participated. Three of the normal subjects experienced the "inversion illusion," and two did not. The illusion consisted essentially in the feeling and awareness that they were "upright" and that the aircraft was flying upside down. The two who did not experience the illusion, in contrast to the three who did, were highly sophisticated subjects who regularly participated in parabolic flights as part of their duty assignment. Three of the L-D subjects were exposed to two experimental trials and one to three. None experienced a true inversion illusion. These findings strongly suggest if they do not prove that the inversion illusion has its genesis in the otolith system.

Completed Reports

While quantity is by no means everything, we still note with some satisfaction that the 100th report has been "passed" in this quarter.

97. Kennedy, R. S., Wood, C. D., Graybiel, A., and McDonough, R. G., Side effects of some anti-motion sickness drugs as measured by psychomotor test and questionnaires.
98. Riccio, D. C., Igarashi, M., and Eskin, A., Modification of vestibular sensitivity in the rat.
99. Correia, M. J., Hixson, W. C., and Niven, J. I., Otolith shear and the visual perception of force direction: Discrepancies and a proposed resolution.
100. Niven, J. I., Hixson, W. C., and Correia, M. J., Elicitation of horizontal nystagmus by periodic linear acceleration.
101. Hixson, W. C., Niven, J. I., and Correia, M. J., A man-referenced vestibular acceleration nomenclature of kinematics form: Basic notation.
102. Wood, C. D., Kennedy, R. S., Graybiel, A., and Wherry, R. J., Jr., Computer library literature review on effectiveness of anti-motion sickness drugs.
103. Wood, C. D., Kennedy, R. S., and Graybiel, A., Evaluation of drugs for motion sickness.
104. Wood, C. D., Graybiel, A., and Kennedy, R. S., Human centrifuge studies on motion sickness.
105. Igarashi, M., and New, A. E., Spontaneous ear infection in the albino rat.